Effects of Driver Fatigue Monitoring – An Expert Survey

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Abstract. On long journeys under monotonous road conditions, fatigue monitoring systems might help to reduce sleep-related crashes by informing or alerting the driver, or even by taking corrective actions in the driving task. The objective of this study was to find out more about the view of experts on future driver fatigue monitoring. A questionnaire was designed to discover the objectives and the predicted effects of these systems. Evaluations of 19 researchers and 52 professional drivers were compared to each other. Researchers predict positive effects of fatigue monitoring, as the reduction of accidents, but do not deny possible hazards due to behavioral adaptation. Professional drivers claim it is particularly important to develop an affirmative attitude towards driving without fatigue and see potential in enhancing the individual responsibility of the drivers.

Keywords: driver, fatigue, sleepiness, drowsiness, monitoring, assistance system, expert survey, behavioral adaptation.

1 Introduction

1.1 Monitoring Driver Fatigue

On long journeys under undemanding and monotonous road conditions, sleepiness of the driver poses a serious hazard. Particularly professional drivers with a high driving performance, like long distance lorry drivers, are confronted with the risk of falling asleep at the wheel (e.g. Horne & Reyner, 1999). Driver fatigue (sleepiness, tiredness) is the largest identifiable and preventable cause of road accidents worldwide, accounting for approximately 15-20% of all accidents, with official statistics often underestimating this contribution (consensus statement of an international group of scientists, 2000). The development of new technologies for driver fatigue monitoring is an attempt to reduce sleep-related crashes by informing or alerting the driver, or even by taking corrective actions in the driving task (see European projects like SAVE "System for effective Assessment of the driver state and Vehicle control in Emergency situations" and AWAKE "Assessment of driver vigilance and Warning According to traffic risK Estimation"). These new systems do not only raise crucial questions concerning the technical realization but also in terms of their consequences

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on driver activity. The introduction of new safety systems does not always result in the desired increase in safety, as has been shown in the past (Hoedemaeker and Brookhuis, 1998; Ward et al., 1995; Rudin-Brown and Noy, 2003; Rudin-Brown and Parker, 2003; Sagberg et al., 1997; Ward et al., 1996). Explanatory models like "risk homeostasis" theory (Wilde, 1994) and "zero-risk" theory (Summala, 1988) imply that any safety system in the car will have a limited effect, due to behavioural adaptation. These adaptations may also appear as a result of the introduction of a fatigue monitoring system and possibly undermine its expected safety benefits. Driver monitorring devices might even encourage sleepy drivers to take further risks and to continue driving.

A lot has been achieved in predicting or detecting driver drowsiness (e.g. SENSATION project). What remains unresolved is 1) how to respond to a drowsy driver and 2) what kind of effect to anticipate with different feedbacks. Regarding the human-machine-interface it is crucial for the success of such a system to find out to what extent interface and feedback have an impact on situational risk perception and behaviour of the driver.

1.2 Objective

The objective of this study was to shed light on "the experts' view" on driver fatigue monitoring. To find out more about objectives and predicted effects of driver fatigue monitoring, a survey was conducted. In point of fact, the survey had two expert groups. One of the expert groups consisted of researchers working in the field of driver fatigue monitoring. The other group has a different kind of expert knowledge that derives from the direct experience with driver fatigue: professional drivers. We also intended to examine differences between the expert groups.

2 Method

2.1 Questionnaire

A questionnaire was designed to discover the objectives and the predicted effects of driver fatigue monitoring. In addition, demographics like age and gender were collected, as well as measures on expertise.

The main objective of driver fatigue monitoring is to reduce numbers of fatigue-related accidents. Different ways of how this can be accomplished are objectives on a subordinate level. In the first part of the questionnaire these objectives had to be ranked by their relevance by putting a '1' next to the one considered most important, a '2' next to the one next most important, and so on down to '5'. The objectives were: a) activate drivers to manage fatigue while driving, b) adapt the thresholds of other assistance- and safety-systems (such as adaptive cruise control) depending on the fatigue level, c) develop an affirmative attitude towards driving without fatigue, d) educate drivers about the signs of fatigue, e) improve drivers' awareness of the risks of fatigue while driving, f) increase drivers' general understanding of fatigue

development, g) interfere actively in the driving performance to prevent accidents, h) make drivers aware of their own current fatigue level, i) motivate fatigued drivers to take a break, j) warn drivers, before their driving performance decreases seriously or k) another important objective, which could be specified.

In the second part of the questionnaire possible positive and negative outcomes of driver fatigue monitoring were listed as statements. The outcomes were:

- Drivers will have better fatigue awareness with such a device.
- Drivers will cause less road accidents with such a device.
- Drivers will drive more responsibly with such a device.
- Drivers will improve the ability of self-monitoring with such a device.
- Drivers will take more breaks when using such a device.
- Drivers will estimate the risk of driving fatigued more adequately.
- Drivers will drive more safely with such a device.
- Drivers will underestimate the risk of driving fatigued when using such a device.
- Drivers will care less about self-monitoring fatigue with such a device.
- Drivers will overestimate their own driving ability when using such a device.
- Drivers will tend to overtrust such a device.
- Drivers will tend to leave fatigue control to such a device.
- Drivers will be additionally strained by such a device.
- Drivers will be distracted by such a device.
- Drivers will drive longer with such a device.
- Drivers will feel safer with such a device.

The extent to which the respondent agreed or disagreed with the statements had to be indicated on a 5-point rating scale (-2 “strongly disagree”, -1 “disagree”, 0 “neutral”, 1 “agree”, 2 “strongly agree”). The statements related to the effects of three different feedback types which differed in their extent of automation. Respondents were asked to imagine a driver-fatigue monitoring device which 1) interferes actively in the driving performance when the driver falls asleep, 2) warns the driver, before his or her driving performance decreases seriously and 3) continuously informs the driver about his fatigue level. The survey took about 20 minutes to complete.

2.2 Participants

49 questionnaires were sent to researchers all over the world working in the field of driver fatigue monitoring. 23 returned questionnaires were checked for expert status using the criterion of working more than 3 years on the topic. 19 returned forms could be considered. In the group of professional drivers, a total of 52 replies from online and paper forms were analysed.

2.3 Statistical Analyses

All questionnaires were entered into the statistics software SPSS 14.0. Estimations and prognoses of both groups were compared to each other.

To examine the rank order of objectives contributing to the main goal of reducing fatigue-related road accidents, points were assigned according to their rated relevance. The objective ranked as the fifth most important factor received one point, and the objective considered as most relevant received five points, the objectives in between were handled accordingly. Zero points were assigned to non-selected objectives. Average points per objective determined the final rank order.

Rating scales concerning outcomes of driver fatigue monitoring were analysed using an analysis of variance with the within-subjects variable "type of feedback" (interfere / warn / inform) and the between factor "expert group" (research experts / professional drivers). The 0.05 level of significance was adopted for these analyses.

3 Results

3.1 Characteristics of Experts Who Completed Questionnaires

Of the 19 research experts who returned completed questionnaires, 17 were men. Their mean age was 50 years (range 30–81 years). Six identified themselves as citizen of USA, three from Sweden, Netherlands and Germany, and one from France, Canada and Australia. The amount of years that experts reported working as researchers in the field of driver monitoring was more than 10 years for ten participants, and 3 to 10 years for the nine remaining.

49 of the 52 professional drivers were men; except for 3 of them all were German citizens. The mean age was 42 years (range 24–62 years). Approximately 63,5% of the professional drivers were working in truckage companies, 19,2% in bus companies, 11,5% in another sector, 5,8% were not specified. They drove annually an average of 120.000 kilometers (range 20.000-250.000).

3.2 Evaluation of Objectives

Table 1 presents the results for both expert groups. The most important objective from the researchers' view is to warn drivers before their driving performance decreases seriously (2.95), and to make drivers aware of their own current fatigue level (2.37). In comparison to professional drivers, they attach more importance to objectives like activating the driver (1.11) or adapting thresholds of other systems (1.21). Professional drivers see the most promising objective in motivating drivers to take a break (2.15) and improving drivers' awareness of the risks of fatigue while driving (1.94). They also differ from researchers in ascribing more importance to increasing the general understanding of fatigue development (1.08) or to developing an affirmative attitude towards driving without fatigue (1.60). Both groups agree in attaching importance to motivating drivers to take a break (2.11; 2.15).

Table 1. Mean score for objectives according to researchers and professional drivers

Objectives	Researchers	Professional Drivers
Warn drivers, before their driving performance decreases seriously	2.95	1.83
Make drivers aware of their own current fatigue level	2.37	1.67
Activate drivers to manage fatigue while driving	1.11	0.69
Adapt the thresholds of other assistance- and safety-systems (such as ACC) depending on the fatigue level	1.21	1.04
Interfere actively in the driving performance to prevent accidents	1.79	1.69
Motivate drivers to take a break	2.11	2.15
Develop an affirmative attitude towards driving without fatigue	1.26	1.60
Increase drivers' general understanding of fatigue development	0.47	1.08
Educate drivers about the signs of fatigue	1.05	1.69
Improve drivers' awareness of the risks of fatigue while driving	1.16	1.94

3.3 Feedback Effects

The ANOVA indicated some significant differences between the predicted effects of the three feedback types (interfere / warn / inform). There are concerns in both groups that drivers will underestimate the risk of driving fatigued primarily when using an interfering device (see table 2). For researchers, the danger of driving longer than before is related to the degree of automation of the system, as it is considered highest with the interfering device. Professional drivers judge the interfering system as most promising to reduce accident numbers. Researchers favour the warning feedback over the interfering system. In comparison, a continuously informing device is seen as most suitable to enhance fatigue awareness and self-monitoring. Yet, strain and distraction is also seen as highest with this kind of feedback. All reported differences were significant on the 0.05 level.

There were also significant differences between the judgements of both expert groups. Research experts had generally a much more optimistic view on driver fatigue monitoring systems than professional drivers. They assumed better fatigue awareness, fewer accidents, more adequate risk estimation, improved self-monitoring and more breaks when implementing such systems than the drivers. However, they also saw more risk of driving longer than professional drivers. All these reported differences were significant on the 0.05 level.

Table 2. Mean ratings for expert group and feedback type (scale from -2 to 2)

	Expert group	Researcher			Professional Driver		
Drivers will …	Feedback type	Interfere	Warn	Inform	Interfere	Warn	Inform
… underestimate the risk of driving fatigued when using such a device.		0.47	0.11	-0.35	0.49	-0.08	-0.20
… have better fatigue awareness with such a device.		0.63	0.89	1.24	-0.39	-0.31	-0.13
… be additionally strained by such a device.		-0.74	-0.50	0.06	-0.47	-0.67	0.04
… be distracted by such a device.		-0.53	-0.17	0.25	-0.59	-0.57	0.07
… care less about self-monitoring fatigue with such a device.		0.47	0.61	0.24	0.16	0.17	0.19
… cause less road accidents with such a device.		0.90	1.00	0.65	0.15	-0.09	-0.33
… drive longer with such a device.		0.95	0.67	0.12	-0.59	-0.40	-0.43
… drive more responsibly with such a device.		-0.32	-0.17	0.12	-0.39	-0.43	-0.34
… drive more safely with such a device.		0.42	0.61	0.24	-0.18	-0.22	-0.24
… estimate the risk of driving fatigued more adequately.		0.05	0.11	0.77	-0.37	-0.39	-0.45
… feel safer with such a device.		1.00	1.00	0.82	0.24	0.39	0.29
… improve the ability of self-monitoring with such a device.		0.26	0.72	0.82	-0.50	-0.42	-0.34
… overestimate their own driving ability when using such a device.		0.37	0.39	0.00	-0.32	-0.33	-0.33
… tend to leave fatigue control to such a device.		0.37	0.44	0.29	-0.02	-0.04	0.04
… tend to overtrust such a device.		0.58	0.56	0.47	-0.04	-0.06	-0.04
… take more breaks when using such a device.		0.05	0.06	0.12	-0.66	-0.63	-0.75

4 Discussion

The results of this study demonstrate that researchers working in the field of driver fatigue monitoring see potential in a system which informs and warns drivers, but also activates them and adapts thresholds of other systems. The preferred feedback is more a correction of critical states and actions. Professional drivers place more emphasis on the individual responsibility of the drivers, on motivating them to take a break, improving their awareness of the risks of fatigue while driving, and even on changing drivers' attitude towards driving without fatigue. Here the preferred approach deals more with changing misinterpretations and a reeducation of drivers. The results of the objective ranking might help improve the implementation strategies of such devices. From the view of user-centred design it is important for the developers and designers to give attention to the opinion, the prospects, and the objections of the end user of the

systems' feedback. Experienced drivers seem to value educative campaigns somewhat higher than a direct intervention in their driving task.

Both expert groups agree that an interfering system might lead to an underestimation of the risk of driving fatigued. Indeed, the researchers are quite aware of possible behavioural adaptations, like leaving fatigue control to the system, overestimating the own driving ability or overtrusting the system.

But overall, researchers believe that drivers will cause less road accidents having a driver monitoring device on-board. The general optimism of researchers concerning positive effects of such systems is not shared to the same extent by professional drivers. The latter do not believe that systems might help improve the ability of self-monitoring or even cause drivers to take more breaks. Possibly, they do not see the problem in incorrect fatigue self-assessment but rather in an insufficient responsibility of the drivers. Analysing and foreseeing how drivers are likely to use the system might help to avoid effects such as inducing sleepy drivers to prolong the driving and therefore to fail at reducing accident risk. Future research should investigate how the feedback could be designed to appeal to the drivers' individual responsibility rather than correcting their self-assessment and actions.

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